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DYNAMIC RELATIONSHIP BETWEEN PRECIOUS METALS AND CENTRAL EUROPEAN STOCK MARKETS

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Abstract: High volatility and the contagion effect have led investors to consider alternative instruments as a part of their portfolios to be able to diversify away from the increasing risk in the stock markets. As alternative instruments, one can consider investing in such metals as gold, silver, copper, and platinum. This paper investigates the dynamic relationship between gold, silver, platinum, copper, and the Central European stock markets. The aim of this article is to identify if those metals can be considered as safe haven instruments for investors from the Czech Republic, Hungary, Poland, and Slovakia. The considered period is from 01.01.2007 to 30.06.2020. The calculations of DCC-GARCH model parameters were made by using the professional program OxMetrics by J.A. Doornik. There were 22 metal/metal or metal/index DCC-GARCH realization carried out. Significant differences exist in the correlation structure for two groups of metals. Gold and silver can be considered as an investment asset. Platinum and copper are mainly industrial metals. From this research, one can define silver as a safe haven instrument. During the financial crises, one can also observe the negative values of correlations between gold and indices, which means that gold served as a safe haven.

Keywords: alternative investments, precious metals, DCC-GARCH model, dynamic correlation.

1. Introduction

The last three decades brought the occurrence of a few crises such as the Asian crisis of 1997 which began as an effect of short-term capital outflows, and in 1998 and 1999 the Russian and Brazilian crises started with a chronic fiscal deficit. The global financial crisis of 2007-2008 started with a loss of confidence and resulted in a liquidity crisis which increased as stock markets worldwide crashed. One should also mention the latest crisis, namely the coronavirus pandemic of 2020. Such episodes are characterized by high volatility (Markwat, Kole, & van Dijk, 2009).

Moreover, many studies revealed that these crises increased the correlations between the world's equity markets, and thus with lower diversification potentials (Bayoumi, Fazio, Kumar, & MacDonald, 2007; Climent & Meneu, 2003; Diamandis, 2009; Gilmore, Lucey, & McManus, 2008; Syllignakis & Kouretas, 2011).

High volatility and the contagion effect have led investors to consider alternative instruments as part of their portfolios to be able to diversify away from the increasing risk in the stock markets. Therefore, as alternative instruments, one can consider investing in such metals as gold, silver, copper, and platinum. The application of these metals differs. Over 40% of extracted platinum was used in the automobile industry, especially as a catalyst for waste gas purification in diesel engines (Alonso, Field, & Kirchain, 2012). Gold and silver, on the other hand, are considered investment assets that outweigh their industrial usage. Gold plays an important stabilizing role in financial systems (Baur & McDermott, 2010). Copper is used in electronic equipment such as wiring and motors (60%), roofing and plumbing (20%) and industrial machinery (15%). Copper is used mostly as a pure metal, but when greater hardness is required, it is put into such alloys as brass and bronze (5% of total use) (Emsley, 2003).

The purpose of this paper was to investigate the dynamic relationship between gold, silver, platinum, copper, and the Central European stock markets. This article aimed to identify if those metals can be considered as safe haven instruments for investors from the Czech Republic, Hungary, Poland, and Slovakia.

There are many researchers examining the dynamic relationship between precious metals and developed stock markets.

Baur and McDermott (2010) studied the role of gold as a safe haven against stocks for the major developing and emerging countries. They concluded that gold was both a hedge and a safe haven for major American and European stock markets, but not for large emerging markets such as the BRIC countries. In their paper, Gurgun and Unalmis (2014) analysed the hedge and safe haven properties of gold for some emerging and developing countries. Their results showed that gold acts as a hedge and safe haven in a larger set of countries.

Creti, Joëts, and Mignon (2013) researched the links between 25 commodities markets and the stock market. They used a DCC-GARCH model for a daily spot price series during the period January 2001-November 2011, and showed that dynamic correlations the between commodity and stock markets developed over time and were

highly volatile during the 2007-2008 global financial crisis. However, gold could be considered as a safe haven, keeping its value during financial crises.

Chkili (2016) studied the correlation of BRICS countries and gold with a DCC variant and identified a safe haven status. Sensoy (2013) modelled changes in precious metals and contained them in a DCC model based on a heavy-tailed distribution. Their results suggested that silver and platinum could improve the diversification of portfolios. Mensi, Hammoudeh, and Kang (2017) presented a DCC-FIAPARCH for the connection between BRICS and the developed markets.

Capies, Mills, and Wood (2005), Joy (2011), Ciner (2011), and Roberdo (2013) discovered that gold has served as a hedge asset against USD rate movements. For instance, Joy (2011) researched the role of gold as a hedge or safe haven against the dollar using data for 16 major dollar-paired exchange rates. He indicated that during the period 1986-2008 gold acted as a hedge against the US dollar and had a poor role as a safe haven.

Hood and Malik (2013) estimated the role of some precious metals including gold, silver, and platinum as potential tools for hedging or providing a safe haven in the US stock markets. They discovered that gold acts as a weak safe haven and a strong hedge asset in the US stock markets. Miyazaki, Toyoshima, and Hamori (2012) investigated the dynamic interdependence between gold and the financial markets like equity, foreign exchange, and the bond markets. They concluded that dynamic correlations significantly reduced during the explosion of the dot-com bubble and the occurrence of the terrorist attacks between 2000 and 2001. The correlations also declined during the 2010-2011 European debt crisis.

It is well-known from the literature that precious metals are characterized by specific properties such as asymmetry or long memory in variance (Chkili, 2016; Hammoudeh, Yuan, McAleer, & Thompson, 2010). Gold and silver are also found to bond and show similar persistence in variance (Hammoudeh & Yuan, 2008), which is why it was adjusted the DCC model to account for these asset-specific properties.

In all the mentioned studies there was a consideration of the dynamic relationship between the developed markets and precious metals, but there is a lack of such research in the countries of Central Europe, namely the Czech Republic, Hungary, Poland, and Slovakia. This paper was trying to fill that gap.

2. Methodology and data

In the research an analysis was carried out on the main stock exchange indices, the SAX from Slovakia, PX – Czech Republic, WIG – Poland, and BUX – Hungary, as well as of gold, silver, copper, and platinum in the period from 01.01.2007 to 30.06.2020. Based on the recorded past closing prices, continuously compounded returns were calculated. The precious metals rates come from the Thomson Reuters database and are given in US dollars (this are continuous futures series), while the indices data come from the web-portal stooq.pl. The time series for the observations

of the index and metals for the country concerned were date-adjusted after considering holidays during which there was no trading. All the calculations used daily percentage logarithmic returns defined as $r_t = 100 \cdot \ln \frac{P_t}{P_{t-1}}$, where P_t denotes price of an asset at time t. The basic descriptive statistics for the stock exchange indices and precious metals are presented in Table 1.

Baur and Lucey (2010) determined the conditions to set apart when an asset can act as a diversifier, hedge, and safe haven. According to their classification, a hedge is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio on average. A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average. A safe haven is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil. Baur and Lucey also highlighted that a safe haven is a place of safety that offers investors shelter in extreme market conditions. As in the case of the hedge definition, one can also set apart the cases when an asset is uncorrelated in times of turmoil (weak safe haven) and when there is a significant negative correlation (strong safe haven).

2.1. Dynamic conditional correlation (DCC)

Let $Y_t = (y_{1,t}, \dots, y_{k,t})$ denote the k – sized vector of observation at time t. The total number of observations is $n \in \mathbb{N}$. Let us assume that $E_{t-1}[\varepsilon_{i,t}] = 0$ and $E_{t-1}[\varepsilon_{i,t}, \varepsilon'_{i,t}] = H_t$. The dynamic conditional correlation model of Engle (2002) reads:

$$Y_t = \mu_t + \varepsilon_t, \text{ with } \varepsilon_t = \boldsymbol{H}_t^{1/2}\zeta_t,$$
$$\boldsymbol{H}_t = \boldsymbol{D}_t\boldsymbol{R}_t\boldsymbol{D}_t, \tag{1}$$
$$\boldsymbol{D}_t = \text{diag}\left(\sqrt{h_{11,t}}, \dots, \sqrt{h_{kk,t}}\right),$$

where: μ_t is the k – dimensional conditional mean structure, $\boldsymbol{H}_t$ denotes the $(k \times k)$ – sized conditional variance matrix, ζ_t is a k – dimensional vector of i.i.d. random variables with zero mean and unit variance, $\boldsymbol{R}_t$ is the dynamic correlation matrix of size $(k \times k)$ from which one obtains the time-varying correlation coefficient estimates, and $\boldsymbol{D}_t$ is a diagonal matrix with idiosyncratic conditional variances as entries. Let us assume $\zeta_t \sim St - t_v(0, I_k)$, and let $\xi_{i,t}$ denote the standardized residual with respect to the idiosyncratic volatility given as $\xi_{i,t} = \varepsilon_{i,t}/\sqrt{h_{ii,t}}$. The dynamic correlation matrix then decomposes to:

$$\boldsymbol{R}_t = (\text{diag}\,\boldsymbol{Q}_t)^{-1/2}\boldsymbol{Q}_t(\text{diag}\,\boldsymbol{Q}_t)^{-1/2}, \tag{2}$$

where: $\boldsymbol{Q}_t$ denotes the covariance matrix of the standardized residuals $\xi_t = \left(\xi_{1,t}, \dots, \xi_{k,t}\right)$. Engle (2002) introduced a GARCH(1,1)-like structure on the elements of $\boldsymbol{Q}_t = [q_{ij,t}]_{i,j=1}^{k,k}$ with:

$$q_{ij,t} \coloneqq \bar{\rho}_{ij} + \alpha\left(\xi_{i,t-1}\xi_{j,t-1} - \bar{\rho}_{ij}\right) + \beta\left(q_{ij,t-1} - \bar{\rho}_{ij}\right) = \bar{\rho}_{ij}(1-\alpha-\beta) + \alpha\xi_{i,t-1} + \beta q_{ij,t-1}, \quad (3)$$

which is mean-reverting as long as $\alpha + \beta < 1$ and where $\bar{\rho}_{ij}$ is the unconditional expectation of $q_{ij,t}$ with $\bar{\rho}_{ii} = 1$ for all $i = 1, \ldots, k$. An estimator for the dynamic correlation is then given by:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}} = \frac{\bar{\rho}_{ij}(1-\alpha-\beta) + \alpha\xi_{i,t-1}\xi_{j,t-1} + \beta q_{ij,t-1}}{\sqrt{1-\alpha-\beta+\alpha\xi_{i,t-1}^2 + \beta q_{ii,t-1}}\sqrt{1-\alpha-\beta+\alpha\xi_{j,t-1}^2 + \beta q_{jj,t-1}}}.$$

Rearranging the terms in Eq. (3) in matrix notation yields to:

$$\boldsymbol{Q}_t = \boldsymbol{S}(1-\alpha-\beta) + \alpha\xi_{t-1}\xi'_{t-1} + \beta\boldsymbol{Q}_{t-1}, \quad (4)$$

where: $\boldsymbol{S}$ is the unconditional correlation matrix of the residuals and $\xi_t\xi'_t \in \mathbb{R}^{2x2}$. After Klein (2017) and Mensi et al. (2017) let us adopt the following log-likelihood function for the QML- estimation:

$$LL(\theta) = \frac{nk}{2}\log\left(\frac{1}{(\upsilon-2)\pi}\right) + n\log\left(\frac{\Gamma\left(\frac{\upsilon+k}{2}\right)}{\Gamma\left(\frac{\upsilon}{2}\right)}\right) - \frac{1}{2}\sum_{t=1}^{n}\left[\log(\det(\mathbf{H}_t)) + (\upsilon+k)\log\left(1 + \left(\frac{1}{\upsilon-2}\right)\varepsilon'_t\mathbf{H}_t^{-1}\varepsilon_t\right)\right] = -\frac{nk}{2}\log\left((\upsilon-2)\pi\right) + n\log\left(\frac{\Gamma\left(\frac{\upsilon+k}{2}\right)}{\Gamma\left(\frac{\upsilon}{2}\right)}\right) - \frac{1}{2}\sum_{t=1}^{n}\left[2\log(\det(\mathbf{D}_t)) + \log(\det(\mathbf{R}_t)) + (\upsilon+k)\log\left(1 + \left(\frac{1}{\upsilon-2}\right)\xi'_t\mathbf{R}_t^{-1}\xi_t\right)\right], \quad (5)$$

where: θ means the joined parameter of the respective variance models and DCC framework as well as the distribution parameter υ.

Table 1. Descriptive statistics for the rates of return series on the gold, silver, copper, platinum, and WIG, PX, SAX, BUX indices from 01.01.2007 to 30.06.2020

01.2007-06.2020	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
Gold	–6.66173	9.234725	**0.02898**	**0.985996**	**0.07216**	7.282918
Silver	–17.05870	9.785579	**0.00859**	1.693203	–0.64897	8.326683
Copper	–8.43411	11.214220	–0.00082	1.666002	**0.03417**	3.675221
Platinum	–14.43210	9.575846	–0.00901	1.488837	–0.69850	7.766376
WIG	–13.57570	11.759320	–0.00964	1.663957	–0.76907	7.822628
PX	–18.06440	**19.001360**	–0.02003	1.705430	–0.38183	**16.291140**
SAX	–15.46450	11.186030	–0.01068	1.264947	–0.92237	15.212790
BUX	**–18.31640**	18.252840	–0.00379	2.006726	–0.21632	8.843701

Source: own calculations.

Table 1 presents the descriptive statistics for the rates of return series on gold, silver, copper, platinum, and the WIG, PX, SAX, BUX indices from 01.01.2007 to

30.06.2020. The mean value is close to zero, and in two cases it is positive, while for six instruments it is negative. Volatility measured by standard deviation is moderate for all the considered instruments. The lowest standard deviation is in the case of gold, so one can accept that this type of investment is a rather safe alternative to traditional stock markets. The skewness in six cases is negative, which indicates a long-left tail of the empirical distribution of returns. Kurtosis is high for the SAX and PX indices.

3. Results and discussion

This section presents the research resuts with the use of the methodology mentioned above on the markets of the Czech Republic, Hungary, Poland, and Slovakia. The considered period is from 01.01.2007 to 30.06.2020. The calculations of DCC-GARCH model parameters were made using the professional program OxMetrics by J. A. Doornik.

There were 16 metal/index DCC-GARCH realization made, which are presented in Table 2. One can observe that for gold and silver, the dynamic correlation was fluctuating around zero with periods of negative or positive connections. The pairs of silver/index had the lowest correlation $\bar{\rho}$ value (italic number), which means that silver can be identified as a safe haven instrument. The highest value of correlation $\bar{\rho}$ can be observed for the pairs copper/index and platinum/index, which means that these metals are rather not safe haven instruments. This could be caused by the fact that copper and platinum are industrial metals, rather than investment instruments. In any case, the ARCH effect parameter α is positive and significant for all stock markets. Parameter β is also significant and very close to 1 for all cases, suggesting that volatility is highly persistent for all markets, and Student-t degrees of the freedom parameter v is also highly significant for all markets.

Table 2. The parameters of the DCC-GARCH model of pairwise synchronized return data of chosen metal/metal or metal/index for the period 01.2007-06.2020. Robust standard errors are available upon request

	$\bar{\rho}$	α	β	N
1	2	3	4	5
Gold-WIG	0.046521	0.030163	0.922725	6.545443
Silver-WIG	*–0.002795*	0.127172	0.872785	2.408467
Copper-WIG	**0.078732**	0.018168	0.971812	7.994187
Platinum-WIG	**0.103387**	0.012539	0.982986	8.372208
Gold-PX	0.141013	0.023736	0.937336	6.109530
Silver-PX	*0.015437*	0.221788	0.778113	2.418371
Copper-PX	**0.274882**	0.012359	0.983086	7.748412
Platinum-PX	**0.308203**	0.018198	0.960054	8.073031

1	2	3	4	5
Gold-SAX	0.130598	0.003443	0.989479	4.104430
Silver-SAX	*0.000206*	0.070987	0.909284	2.214041
Copper-SAX	**0.178122**	0.003492	0.996063	4.473083
Platinum-SAX	**0.282774**	0.003059	0.996523	4.746552
Gold-BUX	0.108926	0.014827	0.963037	6.709966
Silver-BUX	*0.015684*	0.179893	0.820071	2.427641
Copper-BUX	**0.229130**	0.010388	0.986050	8.173807
Platinum-BUX	**0.260935**	0.009905	0.984330	8.218382

Source: own calculations.

Figures 1, 2, 3 and 4 present the dynamic correlation for the pair metal/WIG (grey line) and quotations of the WIG index (black line). One can observe downward linear trends of WIG quotations during 2008-2009, September 2011, and the last in March 2020. During these periods, one can also see negative values of correlations. What is important is that during the financial crises, gold served as a safe haven. However, in late 2009 during the extreme market shocks, the correlation turned positive. This raises the question if the safe haven status is a temporal effect in ongoing market turmoil as suggested by Baur and Lucey (2010). At the end of 2015 and beginning of 2016, one can observe the falls of WIG quotations and negative values of correlations.

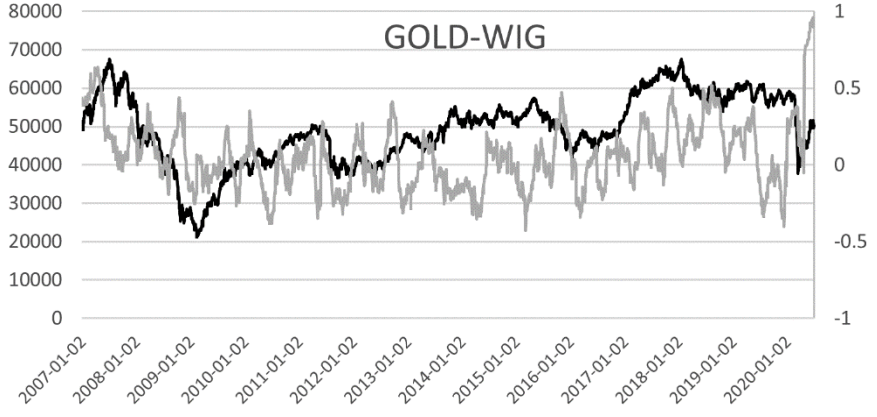

Fig. 1. Dynamic correlation for the pair Gold-WIG (grey line, right axis scale) and WIG quotations (black line, left axis scale)

Source: own elaboration.

From Figure 2 one cannot see such a dependency between the falling WIG quotations and the changing correlation into negative, but there are a lot of periods in which the correlation is negative. This only confirms that silver can be perceived as

a safe haven instrument (the dynamic correlation parameter $\bar{\rho}$ in Table 2 is also negative).

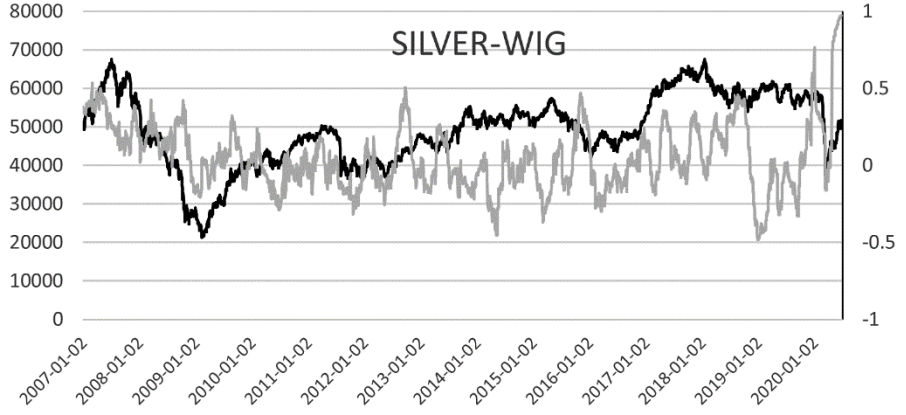

Fig. 2. Dynamic correlation for the pair Silver-WIG (grey line, right axis scale) and WIG quotations (black line, left axis scale)

Source: own elaboration.

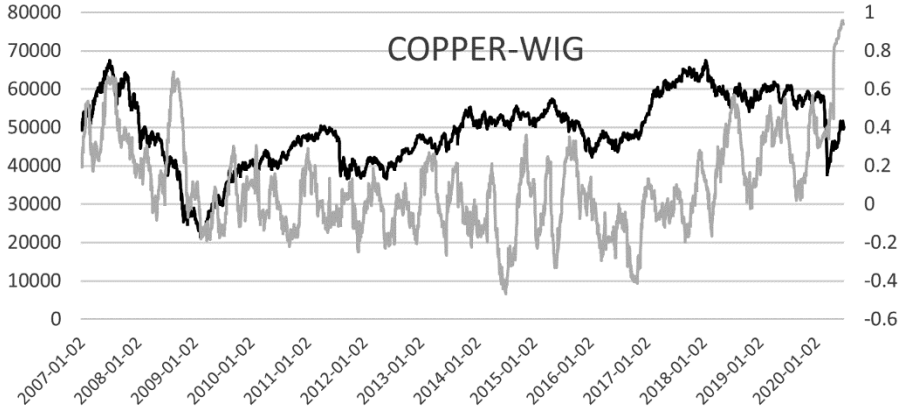

Fig. 3. Dynamic correlation for the pair Copper-WIG (grey line, right axis scale) and WIG quotations (black line, left axis scale)

Source: own elaboration.

From Figures 3 and 4 one cannot see such a dependency between the falling WIG quotations and the changing correlation into negative. This could only mean that investors from Poland do not consider copper and platinum as safe haven instruments. These metals are mainly industrial, so they are not an alternative investment for Polish investors. From the beginning of March 2018 till the end of the considered period, one

can observe positive values of the correlation between copper and WIG and also for platinum and WIG.

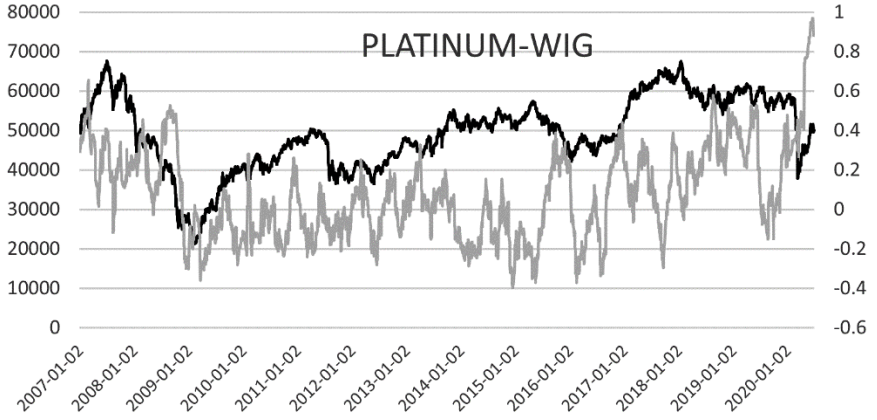

Fig. 4. Dynamic correlation for the pair Platinum-WIG (grey line, right axis scale) and WIG quotations (black line, left axis scale)

Source: own elaboration.

Figures 5, 6 and 7 show a dynamic correlation for the pair silver/index (grey line) and the quotations of an index (black line). From those figures, one can observe that silver can serve as a safe haven instrument for investors from Slovakia and Hungary. Just note that during a crisis, the correlation changes into negative. There are other periods in which one can observe such a dependence, but in this study it is important that such a reliance occurs during the times of crises.

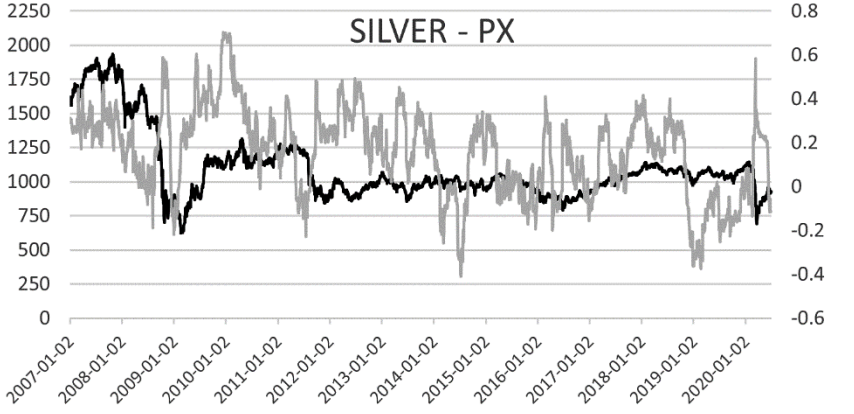

Fig. 5. Dynamic correlation for the pair Silver-PX (grey line, right axis scale) and PX quotations (black line, left axis scale)

Source: own elaboration.

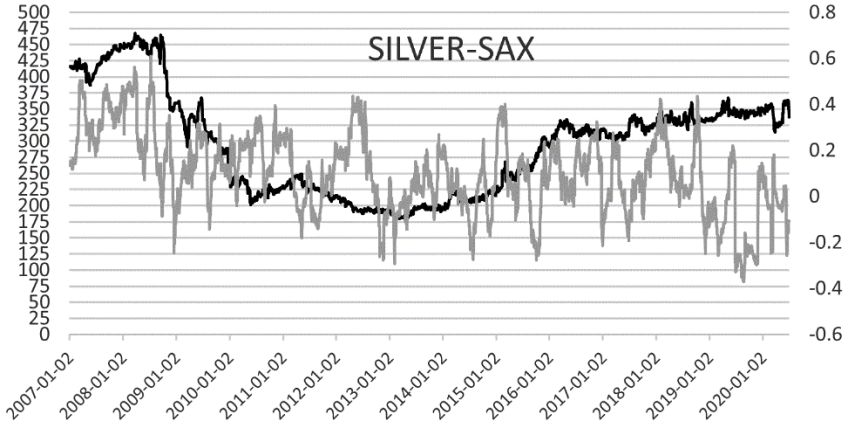

Fig. 6. Dynamic correlation for the pair Silver-SAX (grey line, right axis scale) and SAX quotations (black line, left axis scale)

Source: own elaboration.

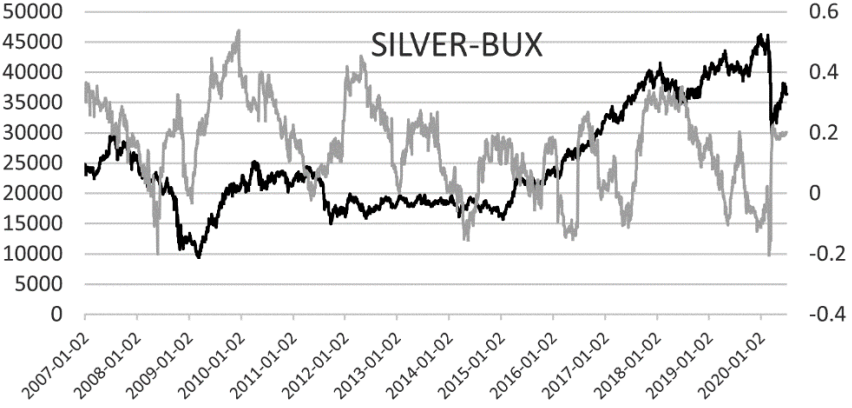

Fig. 7. Dynamic correlation for the pair Silver-BUX (grey line, right axis scale) and BUX quotations (black line, left axis scale)

Source: own elaboration.

4. Conclusion

For centuries, gold and silver have been perceived as important hedging mechanisms against economic uncertainty.

The effectiveness and roles of precious metals in investment portfolios differ for the considered countries. Through analysing data from 2007 to 2020, the authors showed that gold and silver have the potential to play a diversifying role in investment portfolios.

This paper presents the widely used DCC-GARCH of Engle (2002). A lot of researchers have been examining the dynamic relationship between precious metals and developed stock markets, yet there is a lack of such research in the countries of Central Europe, like the Czech Republic, Hungary, Poland, and Slovakia.

The study found significant differences in the correlation structure for two groups of metals. Gold and silver can be considered as an investment asset. Platinum and copper are mainly industrial metals. From this research, one can define silver as a safe haven instrument. During the financial crises, one can also observe the negative values of correlations between gold and indices, which means that gold served as a safe haven.

Comparing these results with other researchers, the authors concluded that silver can also be considered a safe haven instrument. The researchers mostly considered only gold to be a safe haven instrument.

Considerable work remains to be conducted in the area of dynamic conditional correlation. Possible areas of investigation include the dynamic relationship between other alternative instruments such as commodities, e.g. energy products, grain, and oilseed, and other agricultural commodities. Further research might be also interesting, if different modifications of DCC models, like DCC-APARCH, DCC-FIGARCH, DCC-FIAPARCH, and copula-GARCH were to be considered, together with two separate periods for DCC models, one for the financial crisis (2008-2009) and another for the coronavirus pandemic of 2020.

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DYNAMICZNA RELACJA MIĘDZY METALAMI SZLACHETNYMI I RYNKAMI GIEŁDOWYMI KRAJÓW EUROPY ŚRODKOWEJ

Streszczenie: Występująca wysoka zmienność rynków finansowych doprowadziła inwestorów do rozważenia inwestycji alternatywnych jako części swoich portfeli, tak aby zdywersyfikować rosnące ryzyko rynków giełdowych. Jako instrument alternatywny możemy traktować inwestycje w takie metale, jak złoto, srebro, miedź oraz platyna. W artykule przeanalizowano dynamiczną relację między złotem, srebrem, platyną, miedzią oraz rynkami giełdowymi krajów Europy Środkowej. Głównym celem autora jest odpowiedź na pytanie, czy wymienione metale mogą być rozważane jako instrument „bezpiecznej przystani" dla inwestorów z Czech, Węgier, Polski i Słowacji. Pod uwagę brano okres od 01.01.2007 do 30.06.2020 r. Z opracowania wynika, że możemy rozważać srebro jako instrument typu „bezpieczna przystań". Ponadto podczas kryzysu finansowego zaobserwowano negatywną wartość korelacji między złotem a indeksami giełdowymi, co oznacza, że we wspomnianym czasie złoto mogło być postrzegane jako instrument „bezpiecznej przystani".

Słowa kluczowe: inwestycje alternatywne, metale szlachetne, model DCC-GARCH, dynamiczne korelacje.